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EVALUATION OF WELL-WATER SUPPLY
MARINE CORPS BASE
CAMP LEJEUNE, NORTH CAROLINA

By

Harry E. LeGrand

May, 1959

MAY 1959
FINAL REPORT

1422 Chester Road
Raleigh, N. C.
June 10, 1959

Resident Officer in Charge of Construction
Marine Corps Base
Camp Lejeune
N. C.

Dear Sir:

This final report is submitted in accordance with provisions of Contract NBy-7595 dated September 11, 1958.

The report summarizes the geology and underground-water conditions at the Marine Corps Base, Camp Lejeune, N. C., and discusses the results of test drilling done under Contract NBy-7541.

Respectfully submitted,

Harry E. LeGrand

Harry E. LeGrand
Consulting Geologist

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Attachment

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INTRODUCTION

This is the final report prepared in accordance with the provisions of Contract NBy-7595, dated September 11, 1958. It pertains to ground-water conditions at the Marine Corps Base, Camp Lejeune, North Carolina. The work on which this report is based is outlined briefly below.

1. September 11 to October 15, 1958 - Study of ground-water conditions and evaluation of well data available.
2. October 13 to October 23, 1958 - Preparation of preliminary report containing recommendations for drilling 20 test wells (Contract NBy-7541) at various places on the Base.
3. October 23, 1958 to January 15, 1959 - Collection and study of additional data, preparation of monthly progress reports and oral reports to the Public Works Officer.
4. January 15 to June 5, 1959 - Study of test-well data and coordination of test-drilling program with Well Drilling Contractor and the Navy.

   Interim report on Hadnot Point Area submitted March 16.

   Interim report on Tarawa Terrace Area submitted April 3.

   Preparation of final report.

In view of the fact that the preliminary report and the interim reports were larger in scope than originally anticipated, this report contains much material that has been submitted previously.

This report contains no maps or drawings. The following Y & D Drw. Nos. are suitable for reference:

452409 - General Area Map indicating Raw Water Supply Systems and certain other data.

765468 through 765473 - Index sheet and locations for test wells T-1

In addition, 10 sets of U. S. Geological Survey topographic sheets, on which production wells and test wells are located, were submitted with the preliminary report.

Following personal examination of the earth samples from the test holes, the writer submitted the samples to the U. S. Geological Survey office in Raleigh, N. C., for storage. This is the proper depository where anyone can examine the samples at any time in the future.

This report discusses the problems involved in obtaining an adequate quantity of good-quality water from wells and makes recommendations for the future development of water supplies.

GEOLOGY AND NATURAL GROUND-WATER CONDITIONS

All of Onslow County is underlain by sediments that were deposited in or near the ocean. These sediments are composed of sands, clays, marls, and layers of consolidated rocks, such as limestone and sandstone. There is a tendency toward layering, and most of the beds are nearly flat but slope gently toward the coast. These sediments are more than 1,800 feet thick and lie on a floor of hard dense rock such as granite. Only the uppermost few hundred feet of the sediments are important to this discussion, in view of the fact that the deeper sediments are saturated with salty water. The sediments at the surface are chiefly sands that extend to a depth of 10 to 50 feet. The lower part of the "surface-sand unit," locally containing some clay, overlies sediments of Tertiary age. These Tertiary sediments may be considered as a unit and are composed of fine- to medium-grained sands, shells, marls, and consolidated shell beds. It includes chiefly the Castle Hayne formation, but the uppermost part is the Yorktown formation. We may refer to these two formations as the Tertiary unit. Down stream from Jacksonville the channel of New River cuts into this Tertiary unit. Below the Tertiary sediments (at a depth of more than 250 feet) is the Peedee formation, composed of dark sands and clays and thin limestone beds.

All sediments below the water table are completely saturated with water. The water table lies within 10 to 20 feet of the land surface in most places and is in the surface sand. Beds of clay, and perhaps marl, tend to separate the more permeable sand and shellrock beds so that several artesian horizons, or zones, occur in the Tertiary unit. None of the artesian beds are perfect, and there is considerable leakage of water between them where a significant hydraulic gradient exists. This situation arises from the fact that the clayey confining beds are not completely impermeable and from the fact that some beds are not persistent but are somewhat lenticular.

Only in the upper part of the Tertiary unit is there a significant movement of artesian water under natural conditions. Since the Tertiary unit lies in the channel of the river and since the artesian levels are slightly higher than the level of the river, there is leakage of water from the formations into the river. A very large part of the precipitation infiltrates into the surface sand to become underground water. After infiltrating downward to the water table, this water moves laterally toward the nearest surface stream.

WITHDRAWAL OF WATER FROM WELLS

With regard to withdrawal of water from wells at the Base, two aspects of the matter need consideration. One concerns the ability of individual wells to yield water, and the other concerns the ability of the aquifer to yield an acceptable and adequate supply of water perennially.

Most of the wells range in yield from 2 to 10 gallons a minute for each foot of drawdown. This compares unfavorably with yields in other parts of the Tertiary limestone unit extending from the Albemarle Sound through Florida, where the average is greater than 20 gallons a minute per foot of drawdown. The Tertiary unit, in general, is characteristically a shellrock which is made permeable by the removal in solution of the abundant shell material. At Hadnot Point, Tarawa Terrace, and Montford Point the shellrock to a depth of about 250 feet is rather thin and is subordinate in quantity to sand. At any rate, the pumping of sand from the few open-end wells has led to the installation of screened wells to prevent the inflow of sand. The permeability of the sand beds is much less than that of the shellrock beds. Another reason for the low-yielding wells is that the total screened interval is normally less than 50 feet, none of which is below a depth of 200 feet. By utilizing all permeable beds to a depth of 400 feet, much greater yields could be realized. This fact, however, must be tempered with the possibility that water unsuitable to present treatment facilities would be withdrawn. The relation of yield to type of well construction is discussed later in the report.

The safe yield of the aquifer may be considered as the amount of water that can be pumped perennially without bringing in a water of inferior quality. Before the first wells were drilled the hydraulic system in the aquifer was in balance; the natural discharge into New River and perhaps other places was equal to the recharge, and both the water table and artesian levels were more or less fixed in position. When the first wells were drilled this equilibrium was disturbed as water was drawn from storage in the artesian system. Water levels have declined as more wells were pumped. A sufficient amount of water has been drawn from storage to depress the artesian levels over a large area. The water levels will stabilize only when the natural discharge is reduced and the recharge is increased by an amount equal to the amount discharged by the wells.

We have referred to the Tertiary unit as an artesian system, and its early response to pumping wells bears this out. However, there is no perfect seal or confining bed above the aquifer, and, as a result, water from the surface sand moves into the aquifer even through clay beds that occur locally. It is fortunate that this condition prevails in the Hadnot Point area; otherwise, the artesian levels would have lowered much more than they now have, and very likely salty water from the river would have spoiled the aquifer in this area.

With the available data it is impossible to determine accurately the recharge to the aquifer. However, some rough estimate can be made. The infiltration capacity of the surface sand is great. Perhaps between 30 and 40 inches of rain a year reaches the water table in the saturated sand. If the materials extending from the surface sand down to the aquifer are somewhat permeable, a great part of this water will move downward into the limestone unit in the vicinity of pumped wells because the artesian head is considerably less than that of the water table in these places. Under present conditions the downward movement into the limestone is so slow that much of the water in the surficial sand is shunted laterally to a surface stream and thus is not available for recharge. The amount of recharge resulting from downward leakage out of the surface sand is perhaps slightly more than one million gallons a day per square mile in the vicinity of each of the well fields except at the Rifle Range where it may be less. In addition to recharge by downward leakage, there is also recharge by upwward leakage from beds that underlie the level of the lowest well screens. In areas where water is not pumped, the artesian pressure tends to increassc with depth. Therefore, there is natural upward leakage even through cllay beds. When the head is lowered in the aquifer penetrated, the upward lleakage is greatly increased. The combined effects of upward and downward leakkage into the aquifer has caused the water levels in the aquifer to approachn a stablilized condition with less drawdown than would be the case in a peerfect artesian system. Precautionary measures of limiting the drawdown and dispersing the wells have been taken to prevent overpumping. The heavyy pumping in the Hadnot Point area is resulting in a gradual decline of tthe water level in the vicinity of some wells in this area.

CHEMICAL CHARACTER OF WATER

The chemical character of underground water varies considerably with respect to depth and geologic formation. Originally all the beds contained sea water, but in the relatively recent geologic past the fresh-water head has been great enough to push the salty water coastward and seaward to some extent. Salty water has been completely flushed from the uppermost beds, but beds deeper than about 400 feet have been only partly flushed of their original salty water. The beds from which salty water has been flushed now yield water that reflects the chemical character of the rock materials in which it occurs.

Water in the surface sand is soft and contains less than 30 parts per million of dissolved solids. It contains some free carbon dioxide, resulting in a pH value varying between 5.0 and 7.0.

Water in the Tertiary unit is a hard, calcium-bicarbonate water, typical of that in the Tertiary limestone unit extending from the Carolinas into Florida. Except where there is some indication of salt water contamination, the water in this unit commonly ranges in hardness from about 100 to 250 parts per million. Both iron and hydrogen sulfide occur in objectionable quantities at certain places and certain depths. These features are discussed appropriately under the discussion of each area of the Base.

No water is drawn from the Peedee formation, and only a few test wells have been drilled into it. At Hadnot Point the top of the Peedee lies deeper than 250 feet, and it becomes more deeply buried toward the coast. At Piney Green (T-1) the upper part of the formation contains fresh water, but there is evidence that at places nearer New River, the entire formation may contain salty water. Aside from the chloride content, the water in the Peedee is a soft, sodium bicarbonate water, having been softened through cation exchange by natural movement through the glauconite (natural zeolite).

SALT-WATER CONTAMINATION

Where the ancient sea water has been completely flushed out of the underground formations in eastern North Carolina the chloride content of the water is less than about 25 parts per million. Where the chloride content is higher than 25 parts per million there is a suggestion that saltier water is near. Since there are about 19,300 parts of chloride in a million parts of sea water, chloride provides a better indication of salt-water contamination than any other chemical constituent.

There are two ways in which the limestone aquifer at the Base can become contaminated by salt-water intrusion. These are (1) lateral encroachment of water from New River and its tributaries and (2) vertical encroachment from the underlying salt-water beds.

Consideration of possible contamination of the water supply by encroachment of water from New River can be centered on the following points. Although New River does not have the salinity of sea water, it is brackish during much of the year. The degree of its salinity is not very important because it could make an aquifer unusable whether it contains 2,000 or 20,000 parts per million of chloride. New River and the mouthward parts of its tributaries have cut through any impermeable beds that were present and are now entrenched into the Tertiary aquifer. If withdrawal of well water is concentrated close enough to the river so that a hydraulic gradient is established from the river to the center of pumping, salt-water encroachment will occur. Fortunately, proper caution has been taken in the planning of the water supply to prevent lateral encroachment. For example, in the Hadnot Point area the policy has been to limit the drawdown in each well and to locate wells at considerable distances from the salt-water estuaries. As a result of these practices, no contamination has yet occurred. The present data indicate that fresh water of the aquifer is discharging into the river and that the water level has not been lowered sufficiently to reverse the gradient--that is, from the river to the aquifer. A few small observation wells between the river and the production wells would give the water-level measurements needed to clarify this point. The only place where lateral encroachment has actually occurred is at Well 11 on Onslow Beach. This contamination is discussed in the section dealing with Onslow Beach.

The other way in which salt water my reach the aquifer is by upward movement from beds containing salt water. In discussing this point, it is necessary to understand the significance of the relative density of salty water. Since sea water has a specific gravity of 1.025, forty feet of sea water will balance forty-one feet of fresh water. This difference in specific gravity of fresh water and sea water has led to the general rule of 40 to 1 ratio. Where the rule can be applied, the depth in feet below sea level to the contact between fresh and salt water theoretically will be 40 times the number of feet the static level of fresh water is above sea level. The rule cannot be applied to conditions at the Base because of the gradational salinity of water in the ground and because of the absence of homogeneous strata. Nevertheless, it is of value to know that the lowering of the water level in the aquifer a few feet could cause, under certain conditions, the salt water in the underlying bed to rise many feet. The only place where vertical contamination is known to have occurred is at Well E, Camp Geiger. The policy of dispersing wells and of limiting the drawdown in each well, as is the practice at the Base, is the proper precautionary measure to take in preventing vertical contamination. However, more information is needed concerning the depth to salty water and the relative permeability of the materials between the salty water and the zone from which the wells now draw water.

SUMMARY OF THE PROBLEMS

The overall objective of developing the water supply at the Base is to obtain a perennially adequate supply of acceptable chemical quality in the most economical way. This objective is not reached by merely considering the yield of one or even all wells and the treatment that would be necessary. Rather, a number of delicately interdependent factors need consideration separately and collectively. These factors may be grouped in terms of the (1) quantity and (2) chemical quality of the water.

The strict adherence to certain chemical aspects of the water — freedom from chloride contamination and water suitable to present treatment facilities - places limitations on the quantity of water available from the aquifer and from wells.

All water problems are in a sense economic problems, for with an unlimited amount of money, a satisfactory supply of water can be had anywhere in the world. With this thought in mind, we note that the fear of chloride contamination has caused a wide spacing of wells and has caused limitations on the drawdown and yield of the wells. This, in turn, has resulted in a greater expenditure of funds than would have been the case if the problem of chloride contamination were not present. Can wells be spaced closer and can the drawdown and yield of individual wells be increased and still maintain a safe adequate supply? Good judgment has been exercised in developing the water supply at the Base, and a reasonable margin of safety exists insofar as protecting the quality of the water. The deep test holes that were drilled gave valuable information about the salt-water and fresh-water boundaries and about the possibility of salt-water contamination. Yet more information is needed. For example, the maximum safe drawdown of wells at Hadnot Point cannot be determined until "chloride observation" wells are installed, as outlined in the section on Hadnot Point.

Another economic problem concerns the relatively poor specific capacity of the wells (gallons per minute per foot of drawdown). This becomes a significant matter in view of the fact that the gravel-wall type wells, which have been installed, are expensive. The wells have been drilled by competent well contractors, and there is no suggestion that the wells are improperly constructed. Yet some improvement in the economics of wells--either a better specific capacity or reduced cost per well--is one objective. By having electric logs made and samples of rock materials studied from each test hole, the proper placing of well screens and other well construction techniques can be assured.

One reason for the low specific capacity of the wells is the necessity for selecting only those water-producing zones that will yield a water that can be treated satisfactorily at the present treatment plants. For example, some zones of high permeability yield water with excessive amounts of hydrogen sulfide--others with excessive amounts of iron or hardness. It appears more economical, generally speaking, to sacrifice "well yield" in order to obtain the type of water that can be best treated at each plant.

DISCUSSION OF SEPARATE AREAS

On the following pages are brief discussions of the well-water situation at the separate areas where water is used. The discussions cover only those points that are pertinent to the test drilling and to future development of wells.

HADNOT POINT AREA

General Comments

In the Hadnot Point area the character of the rock materials and, therefore, the ability of the materials to transmit water to wells, varies greatly from place to place. Yet, some general comments are appropriate. The materials occur in nearly horizontal beds. To a depth of about 250 feet the beds are composed of fine sand, medium sand, loose shells, shellrock, and clay in varying thicknesses and in varying proportions. The total amount of clay is relatively small. Individual beds are not continuous in character for great distances, and, in fact, the beds cannot be correlated with certainty between one well and another.

The beds of shellrock are, in general, the most permeable, but they are not of sufficient thickness to furnish the optimum amount of water from wells. As a result, the existing wells are multiple-screen, gravel-wall wells that draw water from the more permeable sand and shellrock beds. Most of the wells are screened at intervals between 60 and 200 feet. The yield varies between 3 and 12 gallons a minute per foot of drawdown or 100 to 250 gallons a minute. The wells are dispersed sufficiently so that there is no single composite cone of depression in the water level. It is true that some lowering of the water level at any one of the wells is partly due to the influence of pumping nearby wells. This is a natural consequence of the development of a well field and, in itself, is not detrimental. The control of drawdowns to prevent salt-water encroachment has resulted in a larger number of wells and a greater dispersal of wells than would have been the case if concern about salt-water contamination were not real.

The chloride content of water from all wells is low, and there is no indication that salty ground water is moving toward the well field. Both the water samples and the electric logs of T-8, at the mouth of Frenchs Creek, and T-1, at Piney Green, gave valuable information concerning the relationship between fresh water and salty water. At T-8, on the bank of New River, the fresh-water and salt-water boundary lies at a depth of about 70 feet. This boundary becomes progressively deeper with greater distances from the river, and at T-1 the boundary lies below a depth of 475 feet. Other profiles from the River to inland points probably would show the same relation. The boundary between the fresh- and salt-water bodies is thought to be approximately stationary. Heavy withdrawal from wells close to the river would tend to cause a landward migration of the salt-water body much more readily than would wells further inland. Keeping this boundary from moving toward the wells is one of the most important considerations in maintaining the present supply and in enlarging it.

Thoughts of developing the maximum amount of water from a well at a particular site must be tempered with certain considerations concerning the quality of the water. In addition to the salt-water problem, which has already been discussed, other aspects of the quality of water need to be evaluated in relation to present treatment facilities. The treatment at Hadnot Point adequately handles the hardness and iron content of the water in the zones between depths of 60 and 200 feet. The hydrogen sulfide content appears to be less than that in the same depth-zone at outlying areas of Camp Lejeune. It should be pointed out that relatively permeable sands and shellrock beds commonly occur from the land surface to a depth of 75 feet.

It is likely that large-yielding wells - 100 to 400 gallons per minute per well - could be developed cheaply from this shallow zone. However, the shallow water is corrosive and has a high iron content; this water is not suitable for the present treatment facilities and may not be suitable for distribution through the raw water lines.

Findings and Recommendations

1. Gravel-wall wells, similar to those in use, appear to be the best means of developing water at Hadnot Point.
2. The yields of some wells have been reduced because they pumped fine sand. Since the sands of the water-yielding zones are fine to medium, it is not easy to keep the fine sand out of the wells. As soon as a system is installed to regulate the yield of each well so that it will not be overpumped, some improvement in the fine-sand problem may result.
3. The following comments can be made concerning the area between Wallace Creek and Cowhead Creek (including the area between wells 10 and 26). The best water-yielding zones are between 60 and 200 feet and consist of medium to fine sands. The shellrock zones are rarely more than a few feet thick. The expected yield of future wells is between 175 and 275 gallons a minute, typical of present wells in the area. No wells should be drilled between New River and the Main Service Road because of the danger of causing the salt-water zone to move toward the wells. In order to fully utilize present pipe-line facilities, the following locations appear suitable for new wells:
   (a) T-7 on Holcomb Boulevard.
   (b) About midway between Wallace Creek and Well 10 on Holcomb Boulevard.
   (c) T-2 on Sneads Ferry Road.
   (d) About midway between Wells 6 and 9 on Sneads Ferry Road or about midway between Wells 9 and 26 on Sneads Ferry Road.

(e) T-5 on Old Trailer Camp Road.

4. The area along Sneads Ferry Road south of Cowhead Creek (Wells 27 to 32) is similar to that north of the creek with the following exceptions: the percent of shellrock is slightly greater, the yield per foot of drawdown is slightly better, and there is a slight increase in hydrogen sulfide.

5. The area north of Wallace Creek and extending east of Midway Park to Piney Green is underlain by more permeable materials than in other parts of Hadnot Point. Yields of 6 to 10 gallons per minute per foot of drawdown are to be expected. The depth to salt water is greater than at places near the river. T-1, about 2,000 feet east of Piney Green, had penetrated no salty water at a depth of 475 feet. With this thought in mind, it is satisfactory to draw the water levels lower than in areas nearer the river. Individual wells near Piney Green can be pumped safely at more than 300 gallons per minute with much closer spacing than existing wells at Hadnot Point.

6. If production wells are installed along existing lines where test wells have not been drilled (see item 3 (b) and (d) above), the following comments may be considered. The production wells should not exceed 200 feet. An electric log should be made so that screens can be set at the most permeable zones between 60 and 200 feet. A water-sampling program, in which samples of water would be taken from several zones in a test well, is not necessary because it is now established that the water in the zones between 60 and 200 feet is compatible with present treatment facilities. In fact, a separate test well is not necessary as long as an electric log is made.

7. The present air-line method of measuring water levels is not a satisfactory one for the following reasons: some air lines get stopped up, some leak,

and some have no data concerning their lengths. Moreover, the variableness of gages and the possibility of errors in converting readings from depths to elevations add to the unreliability of the method. It is recommended that the air lines be removed at the earliest convenient time. When this is done, water levels can be measured by the chalked, or wetted, tape method. A 100-foot black, steel tape of moderate stiffness is satisfactory. The tape method of measuring water levels in wells is quicker, cheaper, and more accurate than the air-line method. In the future, water levels in the wells should be measured periodically - perhaps every 3 or 6 months - to determine if pumping at any particular place is detrimental to the safety of the water supply.

8. In order to determine whether the salt-water is encroaching toward the wells, several simple, observation wells should be drilled between the river and the nearest production wells. About five observational wells are needed; three of these should be about 200 feet deep and should be located as follows: between Well 14 and the river, between Well 3 and the river, and between Well 24 and the river. Two observation wells should be about 250 feet deep, one of which could be located 15 or 20 feet from Well 13 and the other about the same distance from the production well at either the T-5 or T-2 location. Samples of water should be collected and analyzed for chloride content every few months. The observation wells would serve as monitors to warn of any approaching salt water before it gets to any of the wells. Any increase in chloride content detected in the observation wells would allow time for an orderly reduction in pumping in that area and an increase in pumping elsewhere. Thus, the maximum safe yield could be realized, the maximum safe drawdown can be determined, and the anxieties of possible salt-water encroachment could be eased.

9. It is estimated that within the area bounded by Wallace Creek, Holcomb

Boulevard, Main Service Road, Sneads Ferry Road, and the Old Trailer Camp Road, an additional withdrawal of two to three million gallons a day can be realized. This includes wells at the sites of T-3, T--4, T-5, and T-6. Any increased withdrawal should be accompanied by adherrence to a "chloride observation" program outlined in item 8 above and a "water-level measuring" program outlined in item 7 above.

10. If an increase in withdrawal greatly exceeding two million gallorns a day is planned, consideration might be given the area within a 1—mile radius of Piney Green.

T-1 - HADNOT POINT

Log

0 - 12	Yellow and blue clay
12 - 41	Fine to medium gray sand
41 - 67	Soft shellrock
67 - 97	Fine gray sand with disseminated phosphate grains
97 - 105	Very fine gray sand
105 - 127	Shellrock and sand in layers
127 - 158	Sand and soft shellrock
158 - 167	Very fine gray sand
167 - 177	Fine to medium gray sand
177 - 237	Medium to fine gray sand
237 - 247	Gray clay
247 - 260	Very fine gray sand
260 - 286	Fine gray sand and disseminated phosphate grains
286 - 311	Clay and soft shellrock interlayered
311 - 332	Shellrock and sand interlayered
332 - 340	Shellrock
340 - 365	Dark gray sandy clay
365 - 388	Shellrock and sandy clay
388 - 391	Dark gray clay
391 - 414	Sand and streaks of rock
414 - 447	Medium gray sand and streaks of shellrock
447 - 477	Dark gray sandy clay

Chemical Quality
(parts per million except pH)

	Depths Sampled		
	63 feet	325 feet	440 feet
Total Hardness	182	226	104
Chloride	12	10	8
Iron	5.0	0.2	0.1
Hydrogen Sulfide	0.3	0.5	0.0
pH		7.6	7.7
Fluoride			0.5

Comments: No production well is presently planned at this site. Both the water samples and electric log indicate that the water is fresh to a depth of 477 feet - perhaps much deeper. Water from the 440-foot zone is of excellent chemical quality. A very permeable shellrock zone occurs between 41 and 67 feet, but the water contains an objectionable amount of iron. A well at this site would be expected to yield more than 500 gallons a minute.

T-2 - HADNOT POINT

Log

0 - 10	Very fine sand and humus
10 - 30	Fine white sand
30 - 40	Medium yellow sand
40 - 50	Medium to coarse sand and scattered shell fragments
50 - 70	Medium gray sand and shell fragments
70 - 80	Medium gray sand but shellrock from 70-73 and 76-78
80 - 110	Fine to medium gray sand
110 - 120	Medium gray sand and shell fragments
120 - 170	Medium gray sand with fine phosphate grains
170 - 180	Medium to coarse gray sand and shells
180 - 240	Fine gray sand

Chemical Quality
(parts per million except pH)

	Depths Sampled	
	150 feet	225 feet
Total Hardness	156	138
Chloride	10	8
Iron	0.6	0.4
Hydrogen Sulfide	0.0	0.0
pH	7.3	7.5

Recommendations for well at site of T-2:

Depth: 180 feet
Gravel-wall well with screen settings at the following depth intervals:

65 - 70	107 - 117
73 - 78	124 - 129
83 - 88	135 - 139
93 - 98	153 - 163
	170 - 177

Estimated yield: 225 gallons a minute with a drawdown of 25 to 30 feet

Tho quality of water is suitable for the present type of treatment.

T-3 - HADNOT POINT

Log

0 - 10	Fine yellow sand
10 - 40	Fine white sand
40 - 58	Medium white sand
58 - 64	Blue clay
64 - 90	Fine to medium white sand
90 - 140	Fine to medium gray sand - some shell fragments
140 - 163	Coarse gray sand - some hard shellrock
163 - 182	Hard shellrock
182 - 200	Medium gray sand
200 - 232	Fine phosphate grains

Chemical Quality
(parts per million except pH)

	Depths Sampled		
	50 feet	150 feet	220 feet
Total Hardness	80	100	110
Chloride	9	8	8
Iron	0.3	0.3	0.6
Hydrogen Sulfide	0.0	0.0	0.0
pH	6.4	7.3	7.3

Recommendations for completed well at site of T-3:

Depth: 200 feet
Gravel-wall well with screen settings at following depth intervals:

71 - 81	141 - 151
95 - 100	159 - 164
119 - 124	186 - 196

Estimated yield: 300 gallons a minute with a drawdown of 30 to 40 feet.

The water has a relatively good chemical quality and is suitable for the present type of treatment.

T-4 - HADNOT POINT

Log

0 - 30	Fine to medium white sand
30 - 52	Medium white sand
52 - 62	Unsorted sand clay and shells
62 - 66	Shell and hard sand
66 - 102	Medium gray sand - a few shell fragments
102 - 112	Soft sandy shellrock
112 - 122	Poorly consolidated sandy shellrock
122 - 134	Soft gray shellrock
134 - 148	Hard shellrock
148 - 163	Partly consolidated, sandy shellrock
163 - 172	Fine gray sand
172 - 178	Shellrock
178 - 218	Fine gray sand
218 - 254	Fine gray sand and thin zones of shellrock
254 - 262	Very fine gray sand and disseminated fine phosphate

Chemical Quality
(parts per million except pH)

	Depths Sampled	
	180 feet	240 feet
Total Hardness	130	140
Chloride	8	10
Iron	0.5	0.8
Hydrogen Sulfide	No odor	No odor
pH	7.3	7.3

Recommendations for well at site of T-4:

Depth: 215 feet
Gravel-wall well with screen settings at the following depth intervals:

90 - 100	155 - 160
115 - 120	172 - 177
138 - 148	185 - 190
	200 - 210

Estimated yield: 275 gallons a minute with a drawdown of 30 to 35 feet.

The quality of water is suitable for the present type of treatment.

T-5 - HADNOT POINT

Log

0 - 17	Fine to medium light sand
17 - 19	Fine sand and clay
19 - 35	Fine light sand
35 - 44	Fine gray sand
44 - 47	Shellrock
47 - 58	Fine gray sand and shells
58 - 60	Hard shellrock
60 - 71	Medium gray sand
71 - 81	Fine to medium gray sand
81 - 95	Medium gray sand and shells
95 - 102	Shellrock
102 - 122	Medium gray sand and shells
122 - 136	Fine to medium gray sand
136 - 155	Hard shellrock and soft streaks
155 - 222	Fine to medium gray sand
222 - 232	Fine sands and interlaminated clay

Chemical Quality
(parts per million except pH)

	Depths Sampled	
	140 feet	210 feet
Total Hardness	176	214
Chloride	10	12
Iron	0.6	1.4
Hydrogen Sulfide	0.0	0.0
pH	7.1	7.1

Recommendations for well at site of T-5:

Depth: 190 feet
Gravel-wall well with screen settings at the following depth intervals:

65 - 75	136 - 150
93 - 108	174 - 180
122 - 127	185 - 190

Estimated yield: 225 gallons a minute with a drawdown of 25 to 35 feet.

The quality of water is suitable for present type of treatment.

T-6 - HADNOT POINT

Log

0 - 5	Fine white sand
5 - 17	Fine white sand and sandy clay
17 - 42	Fine to medium gray sand
42 - 62	Fine to medium brown sand
62 - 72	Medium gray sand
72 - 110	Fine gray sand
110 - 122	Poorly consolidated shellrock
122 - 146	Fine to medium gray sand and shells
146 - 166	Shellrock
166 - 182	Sand and thin layers of shellrock
182 - 202	Medium gray sand

Chemical Quality
(parts per million except pH)

	Depths Sampled	
	72 feet	200 feet
Total Hardness	82	138
Chloride	7	8
Iron	0.2	0.1
Hydrogen Sulfide		0.4
pH	6.8	7.2

Recommendations for completed well at site of T-6:

Depth: 170 feet
Gravel-wall well with screen settings at following depth intervals:

71 - 76	127 - 137
101 - 106	147 - 152
115 - 120	156 - 166

Estimated yield: 300 gallons a minute with a drawdown of 30 to 40 feet.

The water has a relatively good chemical quality and is suitable for the present type of treatment.

T-7 - HADNOT POINT

Log

0 - 5	Gray sandy clay
5 - 10	Medium white sand
10 - 32	Blue to black clay - traces of wood
32 - 39	Medium light gray sand
39 - 43	Gray sandy clay with shell fragments
43 - 50	Shells and gray sand
50 - 60	Medium white sand
60 - 80	Medium to fine light-gray sand
80 - 95	Fine light-gray sand
95 - 120	Medium gray sand and streaks of shellrock
120 - 126	Loose shells and medium sand
126 - 129	Shellrock
129 - 152	Medium gray sand and streaks of shellrock
152 - 154	Fine gray sand
154 - 170	Medium gray sand and loose shells
170 - 182	Fine gray sand and loose shells
182 - 194	Medium gray sand and streak of shellrock
194 - 214	Fine gray sand
214 - 225	Fine gray sand and clay

Chemical Quality
(parts per million except pH)

	Depths Sampled	
	140 feet	210 feet
Total Hardness	140	62
Chloride	10	16
Iron	0.6	0.3
Hydrogen Sulfide	0.0	0.0
pH	7.3	7.8

Recommendations for well at site of T-7:

Depth: 190 feet
Gravel-wall well with screen settings at the following depth intervals:

48 - 60	123 - 143
75 - 80	158 - 168
95 - 105	180 - 190

Estimated yield: 200 gallons a minute with a drawdown of 20 to 30 feet

The quality of the water is suitable for the present type of treatment.

T-8 - HADNOT POINT

Log

0 - 10	Fine white sand
10 - 20	Light gray clayey sand
20 - 27	Dark gray clay
27 - 69	Medium gray sand and some shell fragments
69 - 77	Soft shellrock and medium to coarse sand
77 - 96	Shellrock
96 - 102	Shellrock and fine gray sand
102 - 127	Shellrock and fine gray quartz and phosphatic sand
127 - 157	Medium gray sand and some shellrock
157 - 197	Fine gray sand
197 - 218	Fine gray sand and streaks of shellrock
218 - 247	Very fine gray sand
247 - 260	Fine gray sand
260 - 303	Green clay and fine sand
303 - 327	Gray shellrock
327 - 352	Medium salt and pepper sand - some indurated layers - phossphate abundant
352 - 405	Dark gray clay and fine sand
405 - 456	Fine gray sand
456 - 477	Very fine sand and disseminated dark clay
477 - 502	Fine dark gray sand

Chemical Quality
(parts per million except pH)

	Depths Sampled		
	200 feet	320 feet	490 feet
Total Hardness	2300	58	1800
Chloride	6100	290	6500
Iron	0.2	0.2	1.5
Hydrogen Sulfide	0.1	0.5	0.0
pH	7.4	7.8	7.3
Fluoride			0.3

Comments: No production well is planned at this site. The electric loog indicates that the only fresh water occurs shallower than 70 feet.

TARAWA TERRACE AREA

General Comments

The first wells were drilled at Tarawa Terrace in 1951, and since that time seven wells have been in operation intermittently. Some driller's logs and other records are available, but these records have only limited use for the following reasons. Three sets of well numbers have been used - the driller's numbers, the site numbers, and the present numbers. Thus far, it has not been possible to relate these numbers so that a specific well record can be identified with a particular well. Before the test-drilling program started, less was known about the ground-water situation than at other places on the Base. Knowledge has improved with the drilling of three test holes, but information is still not adequate to clearly state the type of additional wells that would be most suitable and the expected yield from each.

The character of the rock materials and their water-bearing properties along Lejeune Boulevard may be summed up as follows:

(1) From the land surface to a depth of about 50 to 60 feet a white to light gray medium-grained sand is the chief material.

(2) Between depths of about 50 to 85 feet one or more limestone beds occur. The limestone varies in degree of hardness and is commonly less than 20 feet thick.

(3) Sand underlies the limestone zone and extends to a depth of more than 200 feet. The sand varies from fine to very fine in grain size.

Of the five wells along Lejeune Boulevard, only well No. 1 now furnishes more than 100 gallons a minute. Most of the water from the five wells comes from depths varying from 50 to 100 feet. The water is typically hard and contains moderate amounts of iron and hydrogen sulfide. Wells Nos. 6 and 7 on the Bell Fork Road need separate consideration. It is thought that these two wells draw much of their water from depths between 150 and 200 feet. At any rate, the yields are relatively good, but the chemical quality is very poor. Water from both wells contains more than 4 parts per million of hydrogen sulfide. Moreover, well No. 6 has nearly 200 parts per million of chloride and well No. 7 nearly 50 parts. Water from these two wells is not suited for present treatment facilities, and in no case can this water be treated economically.

Well Construction

The type of well most suitable for use is known for most areas, but this is not the case at Tarawa Terrace. In fact, it is proper to give serious thought to each of the following types of wells:

(1) well points

(2) gravel-wall wells

(3) regular screened wells

(4) open-end tubular wells

Although water supplies are not commonly developed from well points in the Coastal Plain, the shallow, medium-to-coarse sands that occur at Tarawa Terrace are well suited to this type of well construction. Shallow, 30 to 35-foot wells, extending along existing raw-water lines on Lejeune Boulevard and Bell Fork Road, can furnish much more than the total anticipated supply at Tarawa Terrace. Advantages of this type of well supply include low initial cost and water that is soft, low in dissolved mineral matter, and free from salt-water encroachment. Disadvantages include frequent maintenance inspections and repairs and all problems that result from the corrosiveness of the water. The pH of the shallow water may vary between 5.5 and 6.5, and its corrosive tendency is certain. The well points would deteriorate within several years. Raw-water lines would be subject to corrosion, and the pick-up of iron before reaching the treatment plant might be significant. The present treatment facilities would have little use. Some consideration should be given to the use of shallow wells for furnishing part of the supply. By interspersing well points with deeper wells, the blended water could be treated very simply.

Gravel-wall wells have been traditional at Camp Lejeune, and their success is not disputed. However, many wells, both at Hadnot Point and

Tarawa Terrace, have pumped sand. In order to free the water of sand, the pumping rate must be reduced. The cause of the sand pumping is clear. Almost all the sand below 50 feet throughout Onslow County is surprisingly even grained. The sand is medium to fine and rarely of a coarse texture. The screen size selected is invariably large--commonly 60 slot (slot opening 0.06-inch). Gravel is selected to fit the screen opening instead of the formational sand. Therefore, the gravel is commonly too coarse and allows the fine to medium sand to be drawn through the screen. The pore space between the gravel becomes clogged with fine sand, resulting also in poor well yields. A smaller screen opening would result in less sand pumping but would also result in a poorer yield. If a larger percent of the sand were coarser, the natural development of a well would result in the fine sand being drawn through during the initial period of development; the coarser sand would be arranged around the gravel wall, and the efficiency of the well would be increased.

Regular screened wells are not inferior, and may be superior, to gravel-wall wells in yield and performance if they are properly constructed. Great care must be taken to select the correct screen size and to place the screens at precisely the correct depth. If the slots are too large, the well will pump sand. If the slots are too small and the screens are not placed opposite the best sand, the yield of the well will be poor. Very few drillers in the Southeastern states are competent to install screen wells properly. Therefore, under the system of competitive bidding on well installations the risk of having improperly screened wells installed is too great to take.

Open-end tubular wells are conventional in the Tertiary limestone unit that extends from North Carolina to Florida, and only at Camp Lejeune have other types of wells been used on a large scale. At Hadnot Point, Tarawa Terrace, and Montford Point the limestone, or shellrock, is so thin that the development of sand-free water from open-end tubular wells is not a certainty. There is a very good chance that open-end wells could be successful at Tarawa Terrace. Neither the samples nor the electric log clearly indicate how much of the shellrock zone is hard, consolidated rock. The depth zones in the wells are: T-9 (71 - 97 feet), T-10 (66 - 77), and T-11 (57 - 66). The proper method of construction is to drive the casing into the top of the rock, extend the well as an open hole a few feet deeper, and stop the hole before it passes through the rock into underlying sand. Development of the well should follow the course of alternately pumping the well at a great rate and resting it. After several days of developing the well in this manner, it is presumed to be acceptable if it has not previously filled with sand or collapsed. If sand-free rock wells can be developed, they will have better specific capacities than screened or gravel-wall wells; individual well yields of 200 gallons a minute could be expected.

Findings and Recommendations

1. No wells should be developed along Lejeune Boulevard below the shellrock zone, the bottom of which is less than 100 feet below the ground. Only fine sand lies below the shellrock, and its contribution to the yield of a well is not great. Moreover, the fine sand tends to move through the screens into the wells and into the distribution system.

2. Although not a simple relation, the hydrogen sulfide content of the water tends to increase with depth. Water shallower than 100 feet contains no objectionable quantity of hydrogen sulfide, whereas that below 150 feet contains an objectionable amount.

3. Below a depth of 175 feet the chloride, or salt, content of the water increases significantly. Wells drawing water between depths of 100 and 200 feet need to be watched for possible salt-water encroachment. On the other hand, wells drawing water at depths shallower than 100 feet will not draw in salt water.

4. Freedom from salt-water encroachment, insofar as wells shallower than 100 feet are concerned, permits a greater tolerance of drawdown of the water levels than would be the case in the development of deeper water.

5. The spacing and drawdown of wells are not a primary concern until two or more development wells are completed. To reduce mutual interference from pumping to a minimum and tolerable allowance, a spacing of 600 feet or more between wells is tentatively recommended.

6. The anticipated average yield for new wells cannot be estimated within narrow limits until at least one new development well is installed. It is safe to assume that gravel-wall wells, screening the best water-bearing materials between 40 and 100 feet, will average more than 125 gallons a minute--perhaps more than 150 gallons a minute. It is suggested that an

attempt be made to develop an open-end well in the shellrock. The cheapness of this type of well and its great potential yield merit consideration. It would be inadvisable for a well contractor who specializes in screened and gravel-wall wells to install this type of well.

7. By developing wells along existing raw-water lines on Lejeune Boulevard and on Tarawa Boulevard into the water plant, a perennially dependable supply of more than $1\frac{1}{2}$ million gallons a day is available. This amount does not exceed the rate of recharge. Additional water can be had from wells shallower than 100 feet along Bell Fork Road, although the character of materials and their water-yielding properties are not clearly known along this road.

8. If all water to be treated at Tarawa Terrace comes from a depth of 50 to 100 feet, the water should be treated for hardness and iron content. The hardness of the composite water is less than 180 parts per million but more than 100 parts per million. The amount of iron in the composite water cannot be determined at this time and may be as low as .2 or as high as 1.00 part per million. The possibility exists that the iron content may be so slight that no treatment for it would be necessary.

Water in the zone that ranges between 75 and 125 feet has a maximum hardness of about 190 parts per million. The water is typically a calcium bicarbonate water, and the total hardness and the total alkalinity are approximately the same. Below 125 feet the hardness decreases with increased depth as a natural ion exchange involving calcium and sodium takes place. At a depth greater than 200 feet the water is a relatively soft, sodium bicarbonate water. The present lime treatment for hardness at Tarawa Terrace is suited for the hard calcium bicarbonate water that occurs to a depth of 125 feet but is not suited for treatment of deeper water.

T-9 - TARAWA TERRACE

Log

0 - 7	Dark gray clayey sand
7 - 52	Coarse white sand
52 - 71	Medium white sand with small amount of clay
71 - 97	Interlayered shellrock and medium sand
97 - 115	Very fine gray sand and some disseminated clay
115 - 142	Fine gray sand
142 - 158	Very fine gray sand
158 - 177	Fine gray sand
177 - 202	Dark gray clay

Chemical Quality
(parts per million except pH)

	Depths Sampled	
	125 feet	175 feet
Total Hardness	146	108
Chloride	12	12
Iron	4.0	0.2
Hydrogen Sulfide	0.6	0.1
pH	7.2	7.8

Tentative recommendations for well at site of T-9:

Depth: 88 feet
Gravel-wall well with screen settings at the following depth intervals:

37 - 42
50 - 60
68 - 72
83 - 88

Estimated yield: 175 gallons a minute
After treatment for hardness and iron content, water will be of good quality.

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T-10 - TARAWA TERRACE

Log

0 - 7	White to gray sandy clay
7 - 27	Medium to coarse light gray sand
27 - 47	Medium to fine gray sand
47 - 66	Medium to fine gray sand and shells
66 - 77	Shellrock and fine sand in streaks
77 - 90	Very fine gray sand and clay
90 - 123	Fine gray sand
123 - 137	Very fine gray sand
137 - 156	Fine gray sand
156 - 177	Very fine gray sand, a little clay matrix
177 - 207	Very fine gray sand and clay mixed
207 - 220	Very fine sand
220 - 247	Very fine gray sand and clay mixed
247 - 250	Fine sand and sandstone

Chemical Quality
(parts per million except pH)

	Depths Sampled		
	50 feet	125 feet	250 feet
Total Hardness	36	168	44
Chloride	10	22	182
Iron	-	0.6	0.2
Hydrogen Sulfide	0.1	0.6	0.9
pH	6.0	8.0	8.2

Tentative recommendations for well at site of T-10:

Depth: 77 feet
Gravel-wall well with screen settings at the following depth intervals:

47 - 57
67 - 77

Estimated yield: 150 gallons a minute.
After treatment for hardness and iron content, water will be of good quality.

T-11 - TARAWA TERRACE

Log

0 - 8	Yellow clay
8 - 17	Fine pink sand
17 - 57	Fine to medium white sand
57 - 62	Shellrock
62 - 66	Medium gray sand and shellrock
66 - 98	Fine gray sand
98 - 110	Very fine gray sand
110 - 132	Fine gray sand
132 - 182	Very fine gray sand and sandy clay
182 - 202	Very fine gray sand

Chemical Quality
(parts per million except pH)

	Depths Sampled	
	85 feet	125 feet
Total Hardness	182	188
Chloride	10	14
Iron	0.2	1.3
Hydrogen Sulfide	0.4	0.5

Tentative recommendations for well at site of T-11:

Depth: 70 feet
Gravel-wall well with screen settings at the following depth intervals:

47 - 57
57 - 62
68 - 73

Estimated yield: 150 gallons a minute.
After treatment for hardness and iron content, water will be of good quality.

MONTFORD POINT AREA

General Comments

Wells at Montford Point draw water only from the upper part of the limestone unit, most of the wells having two short screens at various depth intervals between 50 and 100 feet. The wells vary in yield from 2 to 7 gallons a minute per foot of drawdown, and only one or two wells are pumped at more than 125 gallons a minute. Water in the 50 to 100-foot zone is treated effectively by the zeolite process and is chlorinated. The raw water varies in hardness from about 150 to 200 parts per million and in iron from about 0.4 to 1 part per million. It contains less than 1 part per million of hydrogen sulfide. The chloride content is less than 20 parts per million.

According to results of two test wells drilled deeper than 100 feet at Montford Point, the hydrogen sulfide content seems to increase greatly with increased depth in the limestone unit. The yield per well also would be expected to increase greatly with depth. Therefore, these two countering factors need careful consideration prior to the drilling of production wells in the area.

It is understood that the chloride content of water from the well near the White Cemetery was only 28 parts per million. The well was an open-end hole from 164 to 227 feet. It had a yield of 10 gallons a minute per foot of drawdown.

The three test holes (T-12, T-13, and T-14) indicate that the best water-yielding materials lie between a depth of 35 and 90 feet. The following three reasons, when considered together, discourage an attempt to develop water from a lower zone:

1. Fine sand and clay are the chief materials below 90 feet. The contribution of water from the fine sand would not be great.

Moreover, there is a good chance that this fine sand would be drawn through the screens, resulting in sand pumping and an ultimate reduction in well capacity.

2. The hydrogen sulfide content of the water increases greatly below 90 feet, and the present treatment facilities are not suitable to remove the odor.

3. The salt content of the water increases with depth. Although the water between a depth of 90 and 200 feet is not now too salty to use, pumping of water from this zone might cause an increase in salt content of the water. Therefore, the drawdown of the water level from this zone might have to be controlled.

The present wells at Montford Point are gravel-wall wells screened at intervals no deeper than 100 feet. The yields have tended to decline, chiefly because fine sand has clogged the gravel envelopes around the wells, thereby reducing the efficiency of each well. Future gravel-wall wells will probably resemble the past wells, and sustained yields of 100 to 150 gallons per minute per well are to be expected.

The possibility exists that open-end tubular wells into the shellrock could be successful. The important question concerning this type of well is whether it can pump sand-free water after it is properly developed. If so, it represents the cheapest and most productive type of well. The expected yield is about 200 gallons a minute with no more than a 30-foot drawdown.

There is no fear of salt-water contamination by developing wells shallower than 100 feet at Montford Point. This fact, coupled with the fact that pumping of wells in the area has not lowered the water level much, eliminates any great concern about drawdown of water levels in wells. Perhaps it would not be desirable to lower the level more than about 50 feet below the ground surface.

T-12 - MONTFORD POINT

Log

0 - 3	Medium yellow sand
3 - 12	Yellow clay
12 - 18	Fine yellow sand
18 - 20	Blue clay
20 - 39	Medium gray sand
39 - 65	Soft shellrock and medium sand
65 - 77	Shellrock and some sand
77 - 87	Medium sand - some shells
87 - 102	Shellrock and some sand
102 - 127	Gray clay and very fine sand
127 - 152	Fine sandy clay and streaks of rock
152 - 188	Green sandy clay
188 - 202	Medium gray sand and shellrock
202 - 217	Soft shellrock and sand
217 - 252	Hard shellrock and streaks of medium sand
252 - 277	Fine sand and streaks of shellrock
277 - 320	Fine to very fine gray sand and streaks of shellrock
320 - 327	Interlayered sand and shellrock
327 - 352	Dark gray to green sandy clay

Chemical Quality
(parts per million except pH)

	Depths Sampled		
	52 feet	225 feet	320 feet
Total hardness	98	92	20
Chloride	8	48	340
Iron	0.4	0.2	0.1
Hydrogen Sulfide	0.0	1.5	0.2
pH	7.4	7.8	8.0

Comments: No production well is planned at this site. The zone of sand and shellrock between a depth of 40 and 100 feet appears suitable for development of water. However, this site is sufficiently close to the river to allow salty river water to move toward the well.

T-13 - MONTFORD POINT

Log

0 - 6	Medium yellow sand
6 - 15	Brown clayey sand
15 - 42	Medium light gray sand
42 - 52	Medium sand and shells
52 - 77	Shellrock with some soft sand layers
77 - 82	Dark gray clay
82 - 107	Fine gray sand
107 - 143	Gray clay
143 - 167	Very fine sand
167 - 193	Dark gray clay
193 - 211	Very fine dark gray sand
211 - 250	Interlayered shellrock and sand in thin beds

Chemical Quality
(parts per million except pH)

	Depths Sampled		
	50 feet	150 feet	225 feet
Total Hardness	170	106	120
Chloride	10	130	154
Iron	0.1	0.4	1.2
Hydrogen Sulfide	0.5	1.1	1.9
pH	7.6	7.7	7.5
Methyl Orange Alkalinity	266		578

Optional Recommendation: Open-end tubular well no deeper than 74 feet. Cased to top of shellrock at a depth of about 52 feet. If the well does not pump sand after a period of development, it should yield more than 200 gallons a minute.

Alternate Recommendation: Gravel-wall well 77 feet deep. Screened between 42 and 77 feet. Estimated yield: 150 gallons a minute.

The quality of water expected (see 50-foot sample above) is suitable for present treatment facilities.

T-14 - MONTFORD POINT

Log

0 - 7	Fine, white to yellow sand
7 - 35	Fine, gray sand - small shell fragments below 25 feet
35 - 45	Medium, gray sand and shells
45 - 57	Shellrock and coarse sand
57 - 77	Fine, gray sand
77 - 82	Fine to medium gray sand
82 - 113	Fine sand and gray clay
113 - 139	Fine, gray sand
139 - 172	Fine, gray sand and clay
172 - 191	Fine to very fine gray sand
191 - 200	Medium, gray sand, partly consolidated and containing disseminated phosphate grains

Chemical Quality
(parts per million except pH)

	Depths Sampled	
	125 feet	190 feet
Total Hardness	92	136
Methyl Orange Alkalinity	357	381
Chloride	16	22
Iron	0.3	0.2
Hydrogen Sulfide	1.1	1.0
pH	7.9	7.8

Recommendations for well at site of T-14:

Optional recommendation: Open-end tubular well to a depth of about 566 feet - cased to rock at about 45 feet. If well does not pump sand after period of development, the estimated yield is 200 gallons a minute.

Alternate recommendation: Gravel-wall well 135 feet deep with screen settings at the following depth intervals:

35 - 40
45 - 55
61 - 71
77 - 82

Estimated yield: 160 gallons a minute.
The quality of water will be suitable for present treatment facilities.

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CAMP GEIGER AREA

A very delicate relationship exists between the fresh-water and salt-water zones at Camp Geiger. In general, the limestone unit to a depth of 100 feet contains water that is low in chloride, but in the highly permeable shellrock between 100 and 200 feet enough chloride is present to be objectionable or to cause concern about the possibility that it might increase to objectionable amounts.

There may be two reasons for the nearness of brackish water to the land surface in the area of Camp Geiger and Peterfield Point. In the first place, during the interglacial periods of the Ice Age the sea encroached on Onslow County and drowned it. During these times sea water moved easily into the permeable shellrock. The sea water entered the shellrock where it occurs in the present river channel and then moved laterally, pushing the former fresh water westward. Since the sea has withdrawn to its present position, the salt-water head has been decreased and is now slightly less than the fresh-water artesian head. However, the difference in head has not been great enough for the fresh water to completely flush out the sea water. The fact that the chloride content is only a few hundred parts per million at Wells A and D indicates that the flushing process is almost complete and that the chloride content in this zone at some places may be low enough to be acceptable in the water supply. In fact, the wells at Peterfield Point are screened between 100 and 180 feet and yet will yield water with a fairly low chloride content. Secondly, the relatively shallow salt water at Camp Geiger results from New River being an immense ground-water discharge area. It has already been emphasized that New River incises the Tertiary limestone and sand units, causing great leakage from this unit. The test-drilling program also indicates that the Peedee for-mation, which is not used in the water supply and which is not incised by the river, discharges water upward through the limestone into the river. The low artesian head of the Peedee formation near the river and the soft, sodium bicarbonate water (characteristic of the Peedee) in parts of the Tertiary limestone beds near the river are evidence that brackish water from the Peedee is moving upward. The net result of these two conditions is that brackish water is present at almost all depths near the river, not only at Camp Geiger but along all stretches of the river. By placing wells as far as possible from the river, the salt-water problem can be reduced or eliminated.

The great permeability of the shellrock below 100 feet is indicated by the high specific capacity of Wells A and D, as well as those at Peterfield Point. Well A yields 30 gallons a minute per foot of drawdown, and Well 4 at Peterfield Point is reported to yield nearly 60 gallons a minute per foot of drawdown.

With the above considerations in mind, it appears that T-16 and T-17 represent satisfactory locations for production wells, and future wells should be no closer to the river. In no case should production wells be deeper than 200 feet, and they should be shallower if highly permeable zones are present. The deeper the source of the water, the greater is the likelihood that the alkalinity will greatly exceed the hardness. Thus, the type of treatment for hardness may be considered carefully.

T-15 - CAMP GEIGER

Log

0 - 12	Brown sandy clay
12 - 21	Brown and gray sand
21 - 59	Sand and shells
59 - 112	Gray clay
112 - 142	Fine sand and shellrock
142 - 162	Shellrock
162 - 190	Medium to coarse sand and streaks of shellrock
190 - 302	Fine gray sand and streaks of rock
302 - 372	Dark gray sandy clay
372 - 420	Dark gray clay and calcareous shale
420 - 443	Dark gray glauconitic sand
443 - 477	Medium to coarse gray sand

Chemical Quality
(parts per million except pH)

	Depths Sampled		
	150 feet	250 feet	475 feet
Total Hardness	26	20	30
Methyl Orange Alkalinity	414	542	682
Chloride	280	218	790
Iron	0.1	0.8	0.3
Hydrogen Sulfide	1.2	0.6	1.2
pH	8.0		

Comments: No production well is planned at this site. The water is brackish at all depths and not suitable for use. However, the chloride content does not increase until a depth greater than 250 feet is reached.

RIFLE RANGE AREA

Three different zones of the limestone unit have been tapped at the Rifle Range. Production Wells S-1 and T-1 are screened at intervals of 70 to 80 and 63 to 73 feet respectively. Both wells yield more than 10 gallons a minute per foot of drawdown and attest to the high permeability of the consolidated parts of the limestone unit. The most objectionable features of water in this zone are the excessive iron and hydrogen sulfide contents. Well S-1 contains 3.4 parts per million iron, and Well T-1 contains 6.0 parts per million iron. Well S, screened at 4 different intervals between 75 and 130 feet, yields 10 gallons a minute per foot of drawdown. Water from this well contains less iron and hydrogen sulfide than that from the shallower wells. Well T, which has been abandoned, was screened at the following depth intervals: 382-392, 412-422, and 442-452. The yield was only about 4 gallons per minute per foot of drawdown. A complete chemical analysis is not available, but the water is reported to have had a strong odor of hydrogen sulfide.

Even though the well field lies fairly close to New River, chloride contamination of the wells is not likely to be a serious consideration for two reasons. First, impermeable clays of the Yorktown formation overlie the limestone unit to a depth of 40 to 60 feet, and these clays probably underlie New River near the Rifle Range; the clays should be a partial barrier to any tendency toward salt-water encroachment. Secondly, the relatively high yields of the wells with the limited drawdown should discourage salt-water encroachment.

The chief problems do, however, pertain to the quality of the water--the iron content, the high sulfide content, and the ever present hardness content.

The results of the recent test drilling (T-18 and T-19), when considered with information furnished by existing wells, do not clearly indicate the best zone from which water can be developed. Freedom from "salt-water" worries and high yields are assured. The general depth interval between 180 and 300 feet appears to yield water with a lower iron and hydrogen sulfide content and contains permeable materials. If iron content is not a factor to be considered, open-end tubular wells in the shellrock zone between a depth of 60 to 100 feet would be satisfactory.

T-18 - RIFLE RANGE

Log

0 - 15	Light tan medium sand
15 - 27	Gray sandy clay
27 - 47	Green clay
47 - 67	Shells and sand
67 - 77	Shellrock and sand
77 - 107	Fine gray sand
107 - 120	Gray sandy clay
120 - 172	Fine gray sand
172 - 180	Green clay
180 - 243	Shellrock and sand, in streaks
243 - 302	Medium sand - hard sandstone in streaks

Chemical Quality
(parts per million except pH)

	Depths Sampled	
	200 feet	290 feet
Total Hardness	198	200
Methyl Orange Alkalinity	204	211
Chloride	10	10
Iron	0.3	0.5
Hydrogen Sulfide	0.3	0.3
pH	7.4	7.3

Recommendations for well at site of T-18:

Depth: 300 feet

Gravel-wall well with screen settings at the following depth intervals:

180 - 185	245 - 250
200 - 205	260 - 265
213 - 218	280 - 290
230 - 235	

Estimated yield: 300 gallons a minute with drawdown of less than 30 feet.

The water needs to be treated for hardness and iron content.

T-19 - RIFLE RANGE

Log

0 - 8	Fine white sand with black carbonaceous material
8 - 24	Fine white sand
24 - 49	Green clay
49 - 57	Shellrock and coarse sand
57 - 77	Fine gray sand and sandstone
77 - 87	Shellrock
87 - 121	Fine gray sand
121 - 131	Shellrock and fine sand
131 - 161	Fine gray sand

Chemical Quality
(parts per million except pH)

	Depths Sampled	
	80 feet	150 feet
Total Hardness	164	218
Chloride	12	16
Iron	0.7	1.6
Hydrogen Sulfide	0.2	0.3
pH	7.3	7.4
Methyl Orange Alkalinity	155	214

Recommendations for well at site of T-19: Owing to the scarcity of permeable materials and the high iron content of the water, any completed well at this site should draw water from materials between 180 and 300 feet.

Recommended depth: 300 feet

Screen settings cannot be determined prior to drilling the well, but about 40 feet of screen should be sufficient to produce 300 gallons a minute with less than 30-foot drawdown.

The water should be treated for hardness and perhaps for iron content.

COURTHOUSE BAY AREA

Both Wells V and W draw water through wells screened between depths of 30 and 60 feet at the top of the limestone unit. Both wells yield more than 5 gallons a minute for each foot of drawdown, and, thus, yield is not a problem. According to analyses of October 24, 1957, Well W had an iron content of 1.8 parts per million as compared with Well V of 0.6 part per million. Well W had a hydrogen sulfide content of 0.4 part per million as compared with Well V of 1.0 part per million. These variations in chemical character are not understood at present.

T-20 - COURTHOUSE BAY

Log

0 - 6	Fine yellow sand
6 - 12	Yellow clayey sand
12 - 28	Fine white sand
28 - 35	Fine to medium yellow sand
35 - 41	Gray sandy clay
41 - 50	Very fine gray sand
50 - 85	Shellrock
85 - 111	Fine gray sand
111 - 121	Fine sand and shellrock

Chemical Quality
(parts per million except pH)

	Depth Sampled
	72 feet
Total Hardness	118
Chloride	12
Iron	0.5
Hydrogen Sulfide	0.1
pH	7.5
Methyl Orange Alkalinity	119

Recommendations for well at site of T-20:

Depth: 80 feet

Open-end tubular well, cased to hard rock, which is 50 to 60 feet below ground surface.

Estimated yield: 250 gallons a minute with less than 20-foot drawdown.

It might be desirable to treat the water for hardness and iron content.

T-21 - COURTHOUSE BAY

Log

0 - 10	Fine gray sand
10 - 20	Fine sand with some clay
20 - 30	Gray sandy clay
30 - 45	Blue, gray clay
45 - 50	Fine gray sand
50 - 70	Shelly sand and shellrock
90 - 120	Sand and shells

Chemical Quality
(parts per million except pH)

	Depths Sampled	
	63 feet	100 feet
Total Hardness	124	142
Methyl Orange Alkalinity	112	145
Chloride	14	12
Iron	0.6	0.8
Hydrogen Sulfide	0.3	0.2
pH	7.5	7.5

Recommendations for well at site of T-21:

Depth: 67 feet

Open-end tubular well, cased to hard rock, which is 50 to 70 feet below ground surface.

Estimated yield: 250 gallons a minute with less than 25-foot drawdown.

It might be desirable to treat the water for hardness and iron content.

ONSLOW BEACH AREA

Although no test well was originally designated for Onslow Beach, an increase in salt content of Well 22 at the water plant is justification for one test hole.

Both Wells 22 and 23 are about 63 feet deep, and each is screened at the depth intervals of 30 to 40 feet and 52 to 62 feet. The limestone unit is more consolidated here than at Hadnot Point, and it is likely that open-end wells into the shellrock would be satisfactory. Production from this zone is relatively high. For example, Well 22 gives about 10 gallons a minute per foot of drawdown and Well 23 about 6 gallons a minute per foot of drawdown.

The water in this shallow zone is hard and contains considerable iron and hydrogen sulfide. Zeolite treatment and chlorination reduce the undesirable mineral matter to an acceptable point. An analysis of August 22, 1957, showed that Well 22 had a chloride content of 136 parts per million as compared with about 13 parts per million when the well was first drilled. In view of the fact that the Intracoastal Waterway has cut into shellrock of the Yorktown formation less than 2,000 feet from this well, it is likely that high tides have pushed salt water laterally in the shellrock toward the well. If the chloride content of water from this well continues to increase, it should be abandoned.

T-22 - ONSLOW BEACH

Log

0 - 2	Fine sand with black carbonaceous material
2 - 6	Fine white sand
6 - 12	Brown clay
12 - 30	Medium white sand
30 - 35	Medium white sand with clay streaks
35 - 46	Medium white sand
46 - 161	Sand and shellrock in streaks

Chemical Quality
(parts per million except pH)

	Depths Sampled	
	100 feet	150 feet
Total Hardness	154	138
Methyl Orange Alkalinity	154	150
Chloride	14	16
Iron	0.2	0.2
Hydrogen Sulfide	No odor	No odor
pH	7.3	8.1

Recommendations for well at site of T-22:

Depth: 115 feet

Gravel-wall well with screen settings at the following depth intervals:

57 - 62
90 - 105

(An open-end tubular well at this location should also be satisfactory.)

Estimated yield: 250 gallons a minute with less than 25-foot drawdown.

It might be desirable to treat the water for hardness.

SUMMARY

This report describes the ground-water conditions at the various areas where water is used at the Base. Recommendations for future withdrawal of water are made for specific areas. Some of the recommendations are less definite than is desired, and some are tentative. In spite of a considerable volume of data on wells, much of the data is repetitive, and there is insufficient information about certain features of the ground-water conditions. For example, there is an almost adequate amount of information about the water and rock materials to a depth of about 200 feet, but not enough is known about the boundary between the fresh water and underlying salt-water body that lies generally below 200 or 300 feet. The position of this boundary and the nature of materials it lies in and that lie above it should be known with reasonable accuracy in order that optimum withdrawal of water be made. Thus, rather arbitrary limits of permissible drawdown of water levels and spacing of wells have been established. Refinements in these limits can be made at Hadnot Point as soon as the recommended observation-well program is installed.

The question frequently arises concerning the periodic resting of wells. To consider this question, we must think of the well and the water-bearing formation. As far as the well is concerned, the original period of development tends to arrange the sand and gravel in a position that is stable as long as water is moving toward the well along a hydraulic gradient that is not too steep or as long as pumping is at a moderate rate; continuous pumping should not be harmful to the well. In many places in the United States continuous pumping of wells has caused a progressive lowering of the water level, which may have been harmful because of uneconomical pumping lifts or because of the intrusion of water of inferior quality. At Camp

Lejeune, however, the planned dispersion of wells has prevented an excessive lowering of the water levels. Thus, the need for systematic resting of wells is not necessary as long as the withdrawal of water continues to be dispersed.

The type of well best suited for installation is not a simple matter. At Hadnot Point, Tarawa Terrace, and Montford Point gravel-wall wells have been acceptable. Yet, the evidence available does not clearly indicate that those wells are superior to cheaper and more simply constructed wells. This matter is treated under the section dealing with Tarawa Terrace.

The development of water at the various areas of Camp Lejeune has reached a stage at which continuous technical assistance in ground-water hydrology would be worthwhile. Good judgment has been exercised in the past, but increased withdrawal of water will lead to more realistic concern about salt-water encroachment into the present fresh-water system. It is recommended that the U. S. Geological Survey be employed for this work. The work would consist of systematically measuring water levels and sampling the "chloride-observation" wells that are recommended in this report. Water-level measurements and sampling might be done quarterly; yearly, or interim, reports that would include a water table, or piezometric, map should also be made. The cost of this work should vary between $2,500 and $7,500 a year, depending on the scope.